

# Aerocapture as an Enabling Option for Ice Giants Missions

Soumyo Dutta

NASA Langley Research Center, Hampton, VA 23681 (soumyo.dutta@nasa.gov)



## Motivation

Uranus and Neptune, the Ice Giant planets, were one of the top planetary science destinations in the previous Decadal Survey and expected to be in similar position.

Proposed missions to the Ice Giants have traditionally used fully-propulsive orbit insertion capabilities. These proposals require a very long cruise mission (13-17 years) to reach Uranus and Neptune [1,2] with smaller interplanetary approach speeds to reduce the amount of propellant required for the orbit insertion maneuver.

Despite the long cruise duration to lower the approach speed, the orbit insertion maneuver still requires about 1-3 km/s of  $\Delta V$  (change in velocity). The flight systems usually have 50% or more propellant mass percentages [2].

## New Capabilities for Aerocapture

1. Guidance and control schemes have been developed that enable aerocapture under robust conditions with existing entry vehicle configuration. Predictor-corrector guidance and direct force control – that modulates lift and drag directly – can increase robustness to unknown atmosphere and reduce the needed L/D [3,5].
2. New TPS materials have been developed which meet requirements for Uranus and Neptune aerocapture. NASA has developed two TPS materials – HEEET and PICA – that can meet the needs of Ice Giant aerocapture [4].
3. New navigation abilities improve vehicle state knowledge for Ice Giant missions. Optical Navigation (OpNAV) and Autonomous Navigation (AutoNAV) allow faster spacecraft-to-planet ranging and reduces navigation uncertainty [4].

## References

- [1] Lockwood, M.K., Neptune Aerocapture, 2004.
- [2] Neptune Odyssey, PMCS, 2020
- [3] Girija, A. J. Spacecraft & Rockets, 2020
- [4] Dutta, S., White Paper for Planetary Decadal Survey, 2020
- [5] Deshmukh, R., Acta Astronautica, 2020

## What is Aerocapture?

Aerocapture is an aerodynamic maneuver, where the spacecraft uses the lift and drag forces created during flight in an atmospheric body to reduce the orbital energy and achieve a desired target orbit.

The aerodynamic orbit insertion maneuver provides a large savings in propulsion needed to change the velocity of the vehicle, since aerodynamic forces rather than propulsive systems provide the change in velocity. Aerocapture requires an integrated system level design, including thermal protection systems (TPS), actuator systems for aerodynamic modulation, and guidance and control systems that can autonomously command the change in the aeroassist forces.

## Benefits for the Ice Giants

The largest mass savings for aerocapture occur for the Ice Giants planets due to the large hyperbolic velocities of the interplanetary trajectories that require large propellant mass with traditional orbit insertion. Past NASA studies have shown aerocapture can increase the on-orbit mass by 40% due to lower needed propellant mass[1]. This translates to reduced launch vehicle requirements or additional science instrumentation.

As the vehicle dips into the planetary atmosphere and has a low initial periapsis altitude, aerocapture allows mission designers to target science orbits with low periapsis altitudes, which are useful for ranging and remote sensing operations.

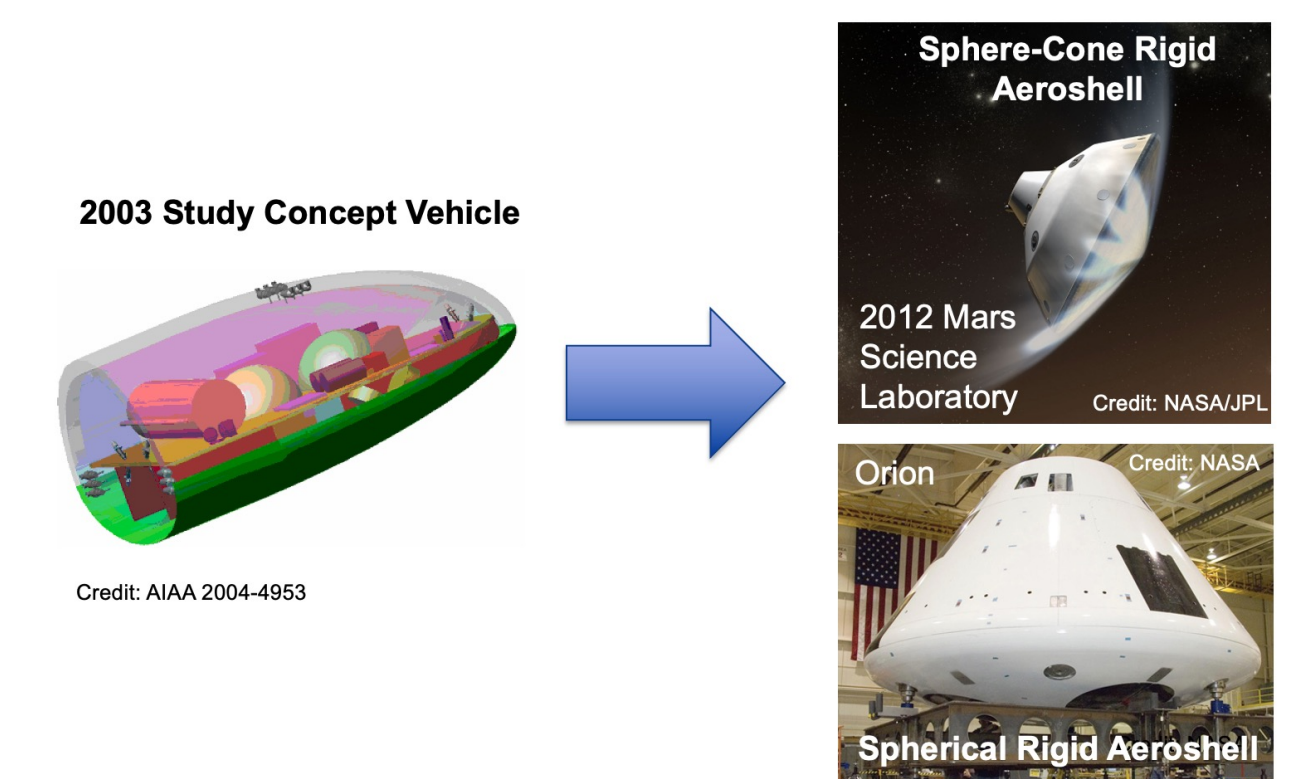
As aerocapture performance is relatively insensitive to increases in hyperbolic excess velocity, the interplanetary trajectory can be designed to arrive at the Ice Giants faster, reducing the interplanetary transit time and operations cost by 3-5 years.

Aerocapture could potentially help fit a larger class mission within a smaller cap, e.g., a Flagship-class orbiter mission in a New Frontiers class cap.

## Aerocapture Concepts

Studies looking at aerocapture for Ice Giants 10-20 years ago recommended the design of a new type of spacecraft, called mid lift-to-drag (L/D) vehicles, due to the needed performance. Due to atmospheric uncertainty and navigation errors, larger L/D is usually required [1].

New capabilities developed and matured in the recent past, allow the use of lower L/D heritage entry vehicles already flown at Earth, Mars, Venus, Titan, and Jupiter to be used for Ice Giants missions [3,4,5].

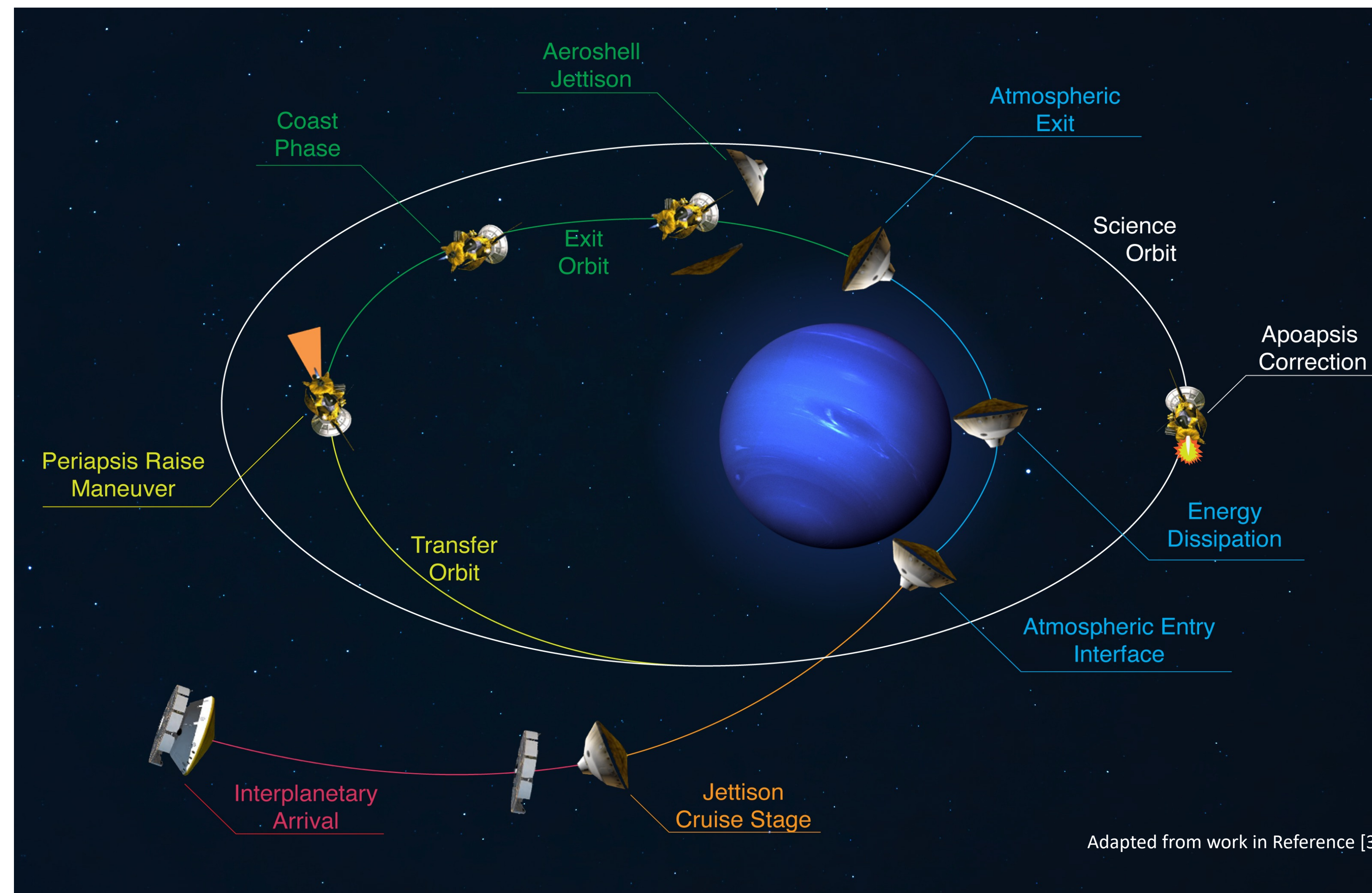


## Aerocapture Readiness for Ice Giants

Aerocapture has been long proposed but has not been demonstrated in a flight mission due a variety of reasons, but never technical deficiency. NASA accepted aerocapture as the baseline mission mode for the proposed Mars 2001 Orbiter mission but went a conservative and traditional route after the failure of Mars Polar Lander and Mars Climate Orbiter, neither of which used aerocapture.

Since then, components of aerocapture, such as active entry guidance, have been demonstrated twice at Mars in arguably more complex scenarios in 2012 and 2021. TPS material capable for aerocapture have been matured and accepted for current flight projects. OpNAV has been demonstrated for Deep Space 1 mission.

All of the features of aerocapture, along with the expertise and technologies that have been developed over NASA's Entry, Descent, and Landing missions in the last 20 years, give high confidence in the ability to successfully implement aerocapture for planetary science destinations, especially the Ice Giants, where aerocapture provides a tremendous advantage in on-orbit mass and transit time.



Adapted from work in Reference [3]